Original Articles (short paper)

Heart rate deflection point as an alternative to determining the anaerobic threshold in dyslipidaemic patients

Rochelle Rocha Costa[1], Thais Reichert[1], Bruna Machado Barroso[1],Vitória de Mello Bones da Rocha[1], Artur Avelino Birk Preissler[1], Éder Santiago[1], Eli Gonçalves Junior[1], Danielle Girolometto Fracalossi[1], Rodrigo Sudatti Delevatti[2], Luiz Fernando Martins Kruel[1]

[1]*Universidade Federal do Rio Grande do Sul, UFRGS, Porto Alegre, RS, Brazil;*
[2]*Universidade Federal de Santa Catarina, UFSC, Campus Reitor João David Ferreira Lima, Florianópolis, SC, Brazil.*

Abstract — Aim: The aim of the present study was to verify the agreement between the ventilatory method (VT) and the alternative method of heart rate deflection point (HRDP) in determining the anaerobic threshold (AT) during incremental treadmill test in dyslipidaemic patients. **Methods:** Twenty-seven dyslipidaemic patients (61.50 ± 10.46 years) performed an incremental treadmill test, in which the AT was determined using both methods. Bland-Altman statistics was adopted in order to verify the agreement between the methods. **Results:** Agreement in AT determination between the VT and HRDP methods was observed ($p < 0.05$) for heart rate (138.00 ± 23.80 and 136.26 ± 22.18 bpm, respectively), oxygen uptake (31.00 ± 10.33 and 31.00 ± 11.17 $ml.kg^{-1}.min^{-1}$), and treadmill velocity (7.67 ± 1.71 $km.h^{-1}$and 8.00 ± 1.75 km.h-1). **Conclusion:** Our results suggest that the HRDP method can be adopted for the determination of the AT in dyslipidaemic patients, showing agreement with the VT method.

Keywords: anaerobic threshold; ventilatory threshold; heart rate deflection point; exercise; dyslipidaemias.

Introduction

Dyslipidaemias can be defined as heterogeneous disorders in lipid metabolism, which result in alterations in blood lipoprotein (low and high-density lipoprotein, LDL, and HDL respectively) and lipid concentrations (total cholesterol and triglycerides, TC and TG, respectively)[1]. This disorder is considered the main risk factor for the development of atherosclerotic cardiovascular disease, increasing the risk of cardiovascular events, such as myocardial infarction, stroke, and peripheral vascular disease[2].

In addition, dyslipidemic patients present lower cardiorespiratory fitness than their normolipidemic pairs[3]. Among the possible reasons, it is highlighted the adverse effects associated with the main class of drugs used for the treatment of dyslipidemia, statins. Statin use is highlighted as the most commonly utilized therapy and can be considered as the most effective pharmacological intervention for LDL reduction[4,5]. However, several adverse events are associated to its use and, among them, myopathy arises as a worrisome side-effect[6]. Evidence adopting muscle biopsy suggests that the use of this class of medications promotes increases in CK levels both, at rest and after exercise[7]. Moreover, in patients treated with statins, even without changes in CK concentrations, was observed important mitochondrial dysfunction and structural muscle damage[8,9]. Furthermore, Mikus et al.[10] have shown that statins users have lower chances to increase their cardiorespiratory fitness and skeletal muscle citrate synthase activity after a period of physical training.

In addition to medication, physical exercise has been recommended as a component of dyslipidaemia treatment[2,3,11]. In this sense, the newest guidelines recommend thepractice of aerobic exercises, such as walking and running, four to six times a week for 30 minutes at a moderate intensity[2]. Nonetheless, it is possible that the myotoxic effects previously mentioned of statins use can influence the regular practice of aerobic exercise, impairing its adhesion and its prescription.

The gold standard parameter for aerobic training prescription is the anaerobic threshold (AT), because it represents the intensity in which the anaerobic contribution increases substantially and the contribution of aerobic metabolism decreases[12]. Thus, the AT provides an accurate knowledge of the metabolic status achieved by the individual during exercise compared to maximal cardiorespiratory parameters (i.e., maximal heart rate, maximal oxygen uptake). The most commonly used non-invasive method for identifying AT is through ventilatory thresholds. The ventilatory curve and ventilatory equivalent analyses enable determination of the breakpoint, at which the respiratory system is unable to effectively buffer H^+ ions, which leads to a disproportional increase in ventilation and carbon dioxide. This breakpoint is known as the second ventilatory threshold (VT_2) and corresponds to the AT[13,14]. However, analysis of ventilatory thresholds requires the use of a gas analyzer, high-cost equipment, which limits its applicability in health clubs and gyms. An alternative method for identifying AT is the determination of the deflection point of the heart rate curve (HRDP). This method is based on the relationship between the heart rate and effort intensity. This relationship is partly linear and partly curved; the intensity of the effort at the point at which the break in linearity occurs (HRDP) is associated with the AT[15]. The identification of AT through the HRDP requires only a cardiac monitor, making this method practical for application.

The agreement between the ventilatory method (VT) and HRDP has already been observed in several modalities in healthy individuals[16-22] and in type 2 diabetes patients[23]. However, no study was found aiming to verify whether HRDP can be used to identify AT in dyslipidaemic patients. Thus, the present study aimed to verify the agreement between the VT and HRDP methods for determination of AT during incremental treadmill test in dyslipidaemic patients.

Methods

Experimental Approach to the Problem

In order to verify the agreement between the VT and HRDP methods in determining the AT of dyslipidaemic patients, an incremental treadmill test was performed. For this, 27 participants completed two laboratory sessions. In the first session, anthropometry measurements were performed and in the second session, the treadmill test was performed.

Participants

The sample consisted of 27 dyslipidaemic patients (10 women and 17 men) who were medicated with statin, non-smokers and free of muscular or joint impairment that prevents from safely performing physical exercises. In addition, patients were familiarized with the treadmill test procedures. The disclosure regarding the experiment was carried out in a specific university extension project for people with dyslipidaemias. Volunteers interested in participating were informed about the study procedures, possible risks and discomforts related to the test prior to signing the informed consent form. After accepting to participate in the study they presented an updated blood test (maximum of three months) confirming lipid values consistent with the dyslipidaemic state (TC > 200 mg.dL-1 or LDL ≥ 130 mg.dL^{-1} or TG ≥ 150 mg.dL^{-1} or HDL < 40 mg.dL^{-1}; isolated or combined)[2]. The study was conducted in accordance with the Declaration of Helsinki and was approved by the Research Ethics Committee of the Universidade Federal do Rio Grande do Sul (protocol 1.571.144).

Procedures

Anthropometry

Body mass and height were measured using a Filizola analog scale (resolution of 0.1 kg) and a Filizola metal stadiometer (resolution of 1 mm) respectively. Using these data, the body mass index (BMI) was calculated. The waist circumference measurement was performed at the midpoint between the iliac crest and the last rib (Cescorf's flexible and inelastic tape measure with a resolution of 1 mm). The same trained evaluator performed all anthropometric evaluations.

Incremental Treadmill Test

An incremental treadmill test (IMBRAMED, model 10200 ATL) was performed with the purpose of determining the AT by the VT and HRDP methods. The test protocol consisted of an initial velocity of 3 km.h^{-1} for 3 minutes, with increments of 1 km.h^{-1} every 2 minutes maintaining a steady slope of 1%. During the test, HR and ventilation records were obtained every 10 seconds. For this, a cardiac monitor (Polar, FS1 model) was used to measure HR, and a portable gas analyzer (INBRAMED, VO2000 model) was used to measure ventilation. The equipment was calibrated according to the manufacturer's instructions prior to each test. The test was interrupted when the patient signaled through manual gestures, which were previously determined, their maximum exhaustion and inability to continue the evaluation. The assessment was considered valid when any of the following criteria were met at the end of the test: respiratory exchange ratio superior to 1.15, a maximal respiratory rate of at least 35 breaths per minute and a rate of perceived exertion (RPE) of at least 18 on Borg's 6–20 RPE Scale[24]. Moreover, the average time to reach exhaustion was 14 minutes, and it is considered optimal for the validity of the maximal tests performed[25].

To the day of the experimental procedure, some restrictions were imposed on the volunteers: no food, drinks or stimulants (i.e., caffeine) to be consumed 3-4 hours before the sessions and no physical activity more intense than daily living activities 12 hours before. They were encouraged to sleep at least eight hours the night before data collection.

Data Treatment

The AT was determined blindly and independently by two experienced physiologists adopting the VT and HRDP methods. In the VT method, the AT was determined as the second inflection point in the intensity by ventilation curve and was confirmed by the CO_2 ventilatory equivalent (V_E/V_{CO2})[26]. In addition, the AT was determined based on the HRDP observed in the HR-by-intensity graph, which is considered the point corresponding to the last deflection in the curve[15]. The point was considered valid when both physiologists identified the same value. In case of disagreement, a third physiologist was recruited.

The HR, velocity, VO_2, $\%HR_{max}$, and $\%VO_{2max}$ corresponding to the point of AT were compared between both methods. In this study, determination of the AT by the VT is considered the gold-standard method.

Analysis

For patients' characteristics, data were presented as mean ± standard deviation. Shapiro-Wilk's test was used to verify the normal distribution of the data. A paired two-tailed Student's t-test was used to compare the variables between the HRDP and VT methods. The Pearson product-moment correlation coefficient demonstrated significant relationships. Additionally, comparisons between the HRDP method and the

VT reference method were performed using the Bland-Altman method, which evaluates the potential existence of agreement or bias. The Bland-Altman analysis uses means and standard deviations to evaluate differences between measurements acquired from the standard and new methods[27]. By analyzing bias and limits of agreement, it is possible to evaluate whether the methods agree. A bias close to zero represents an agreement between the methods. Significance was accepted when $\alpha = 0.05$, and the SPSS statistical software package (SPSS version 22.0, Inc., Chicago, IL, USA) was used to analyse all data.

Results

The characteristics of patients and the descriptive data regarding the maximal and AT variables obtained during the treadmill incremental test are presented in Table 1. All patients performed the test appropriately, and no adverse events were recorded.

The correlation analysis between the HRDP and VT methods showed moderate to strong and significant associations in all variables analysed (Figure 1).

Table 1. Patients characteristics.

	Mean ± SD
Age (years)	61.50 ± 10.46
Total cholesterol (mg.dl^{-1})	175.19 ± 34.06
Triglycerides (mg.dl^{-1})	149.19 ± 48.67
LDL (md.dl^{-1})	99.41 ± 30.01
HDL (mg.dl^{-1})	45.93 ± 10.25
Body mass (kg)	77.94 ± 16.47
Body mass index (kg.m^{-2})	30.26 ± 11.69
Waist circumference (cm)	98.32 ± 15.67
HR_{max} (bpm)	157 ± 20
VO_{2max} (ml.kg^{-1}.min^{-1})	37.55 ± 14.69
V_{max}(km.h^{-1})	9 ± 2

Note: LDL: low-density lipoprotein; HDL: high-density lipoprotein; HR_{max}: maximal heart rate; VO_{2max}: maximal oxygen consumption; V_{max}: maximal velocity.

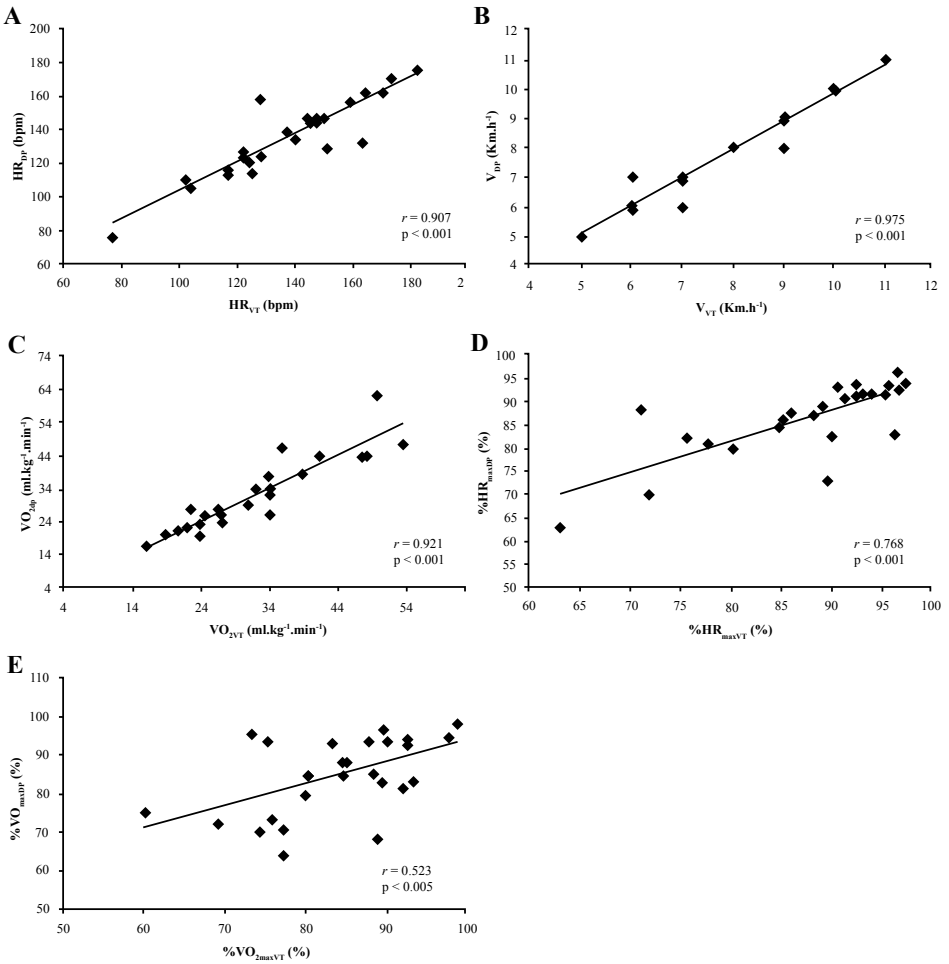

Figure 1. Correlation between the variables corresponding to HRDP and second VT for heart rate (HR) (A), velocity (B), oxygen uptake (VO_2) (C), percentage of maximal HR (%HR_{max}) (D), and percentage of maximal VO2 (%VO_{2max}) (E), during incremental treadmill test.

Note: HRDP: heart rate deflection point; VT: ventilatory threshold.

In addition, Bland-Altman plots showing estimated mean bias and 95% limits of agreement for differences in HR, VO_2, $\%HR_{max}$, $\%VO_{2max}$ and velocity data between HRDP and VT, as plotted against the mean value, are presented in Figure 2. Based on these plot analyses and the results of comparison between the methods (Table 2), there were no differences between the HRDP and VT methods for the HR, VO_2, $\%HR_{max}$, $\%VO_{2max,}$ and velocity, which is indicative of concordance between both methods.

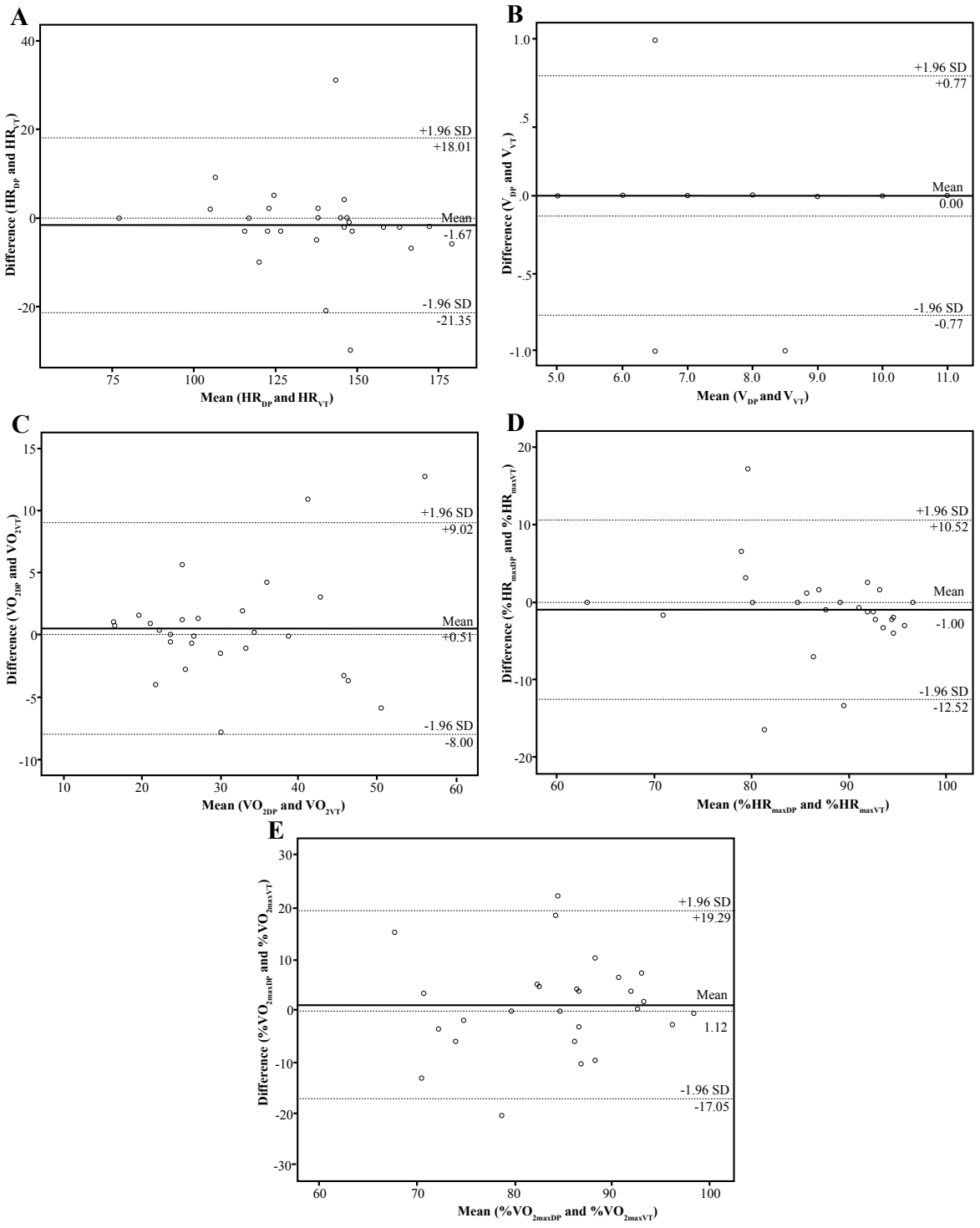

Figure 2. Bland-Altman plots with estimated mean bias and 95% limits of agreement for difference in heart rate (HR) (in bpm) (A), velocity ($Km.h^{-1}$) (B), oxygen uptake (VO2) (in $ml.kg^{-1}.min^{-1}$) (C), percentage of maximal HR ($\%HR_{max}$) (in %) (D), and percentage of maximal VO2 ($\%VO_{2max}$) (in %) (E) corresponding to HRDP and VT, plotted against the mean.

Note: HRDP: heart rate deflection point; VT, ventilatory threshold.

Table 2. Mean and standard deviation (SD) of heart rate (HR), oxygen uptake (VO_2), percentage of maximal heart rate (%HR), percentage of maximal oxygen uptake ($\%VO_{2max}$) and velocity during the incremental treadmill test, based on the determination of anaerobic threshold by the heart rate deflection point (HRDP) and ventilatory (VT) methods.

	HRDP	VT	*p-value*
	Mean ± SD	**Mean ± SD**	
HR (bpm)	136.26 ± 22.18	138.00 ± 23.80	0.397
VO_2 ($ml.kg^{-1}.min^{-1}$)	31.00 ± 11.17	31.00 ± 10.33	0.546
$\%HR_{max}$	87.00 ± 8.02	88.00 ± 9.04	0.383
$\%VO_{2max}$	85.00 ± 9.88	84.00 ± 9.06	0.534
Velocity ($km.h^{-1}$)	7.67 ± 1.71	8.00 ± 1.75	1.000

Discussion

The results of the present study demonstrated that there is an agreement between HR, VO_2 and velocity corresponding to the AT determined by the HRDP and VT methods. This finding reveals that it is possible to prescribe aerobic and anaerobic exercise training for dyslipidaemic patients, using the HRDP method.

The Bland-Altman analysis suggests an acceptable concordance between the HRDP and VT methods for determination of the AT during an incremental treadmill test performed by elderly dyslipidaemic patients. For all evaluated parameters, bias found was very near to zero (0.00 to -1.67), with the majority of the patients without substantial differences between the two methods. But, in some cases, physiological parameters (HR and VO_2) presented the considerable difference between the methods, which can be visualised by limits of agreement (HR: -21.35 bpm to 18.01 bpm; VO_2: -8.00 $ml.kg^{-1}.min^{-1}$ to 9.02 $ml.kg^{-1}.min^{-1}$). Despite these results are in accordance with previous studies, which analysed the agreement between HRDP and VT methods[21,23,28], it needs to be caution in the interpretation and generalization of the results.

The agreement between HR and VO_2 corresponding to AT (HR_{AT} and VO_{2AT}) determined by HRDP and VT was also observed in two other studies[19,20] on young physically active women during treadmill running. Comparing these same methods, Debray & Dey[17] identified an agreement between the HR_{AT} and VO_{2AT} of boys during treadmill running.

Corroborating the present findings, Delevatti et al.[23] identified an agreement between the HR_{AT} and velocity at the AT of type 2 diabetic patients during an incremental treadmill test. Velocity is an alternative parameter for training intensity prescription, for even being the HRDP a less expensive and more accessible alternative for AT determination compared to ventilatory and lactate methods, it yet needs the use of a cardiac monitor, equipment not available to general population. For training prescription by velocity, the cardiac monitor would only be used during the incremental test, and the intensity of training sessions would be easily controlled in treadmills, with electronic devices or by a distance: time relation, which can be calculated for any available place. However, for being the velocity of a mechanical parameter, which represent external load, it can suffer interference of many factors, as time, previous exercise, fatigue and sleep alterations[23]. Other important e simple parameter that can be used is the rating perceived effort (RPE) associated to AT, which was not investigated in this study, but an already present association with gold standards methods, as lactate threshold[29].

Accordingly, the HRDP method could be considered simple to implement, requiring less time (around 15 minutes per patient), easy to be incorporated into a training session, and not requiring an invasive procedure. In addition, the HRDP has been found in both trained[18,21,22] and untrained individuals[16,19,20,28] regardless of the age[17,28] and clinical status[23]. Thus, the estimation of the HRDP may be a non-invasive and easy method to determine the AT, which could be used to set and to prescribe individualized training intensities to diverse populations, including dyslipidaemic patients.

Regarding the mechanisms that explain HRDP in incremental tests, there is not a consensus yet, but this phenomenon has been related to blood K^+ released from working muscles, catecholamine sensitivity of the myocardium, parasympathetic activity, and especially to left ventricular ejection fraction (LVEF) and stroke volume at high exercise intensities[30,31]. In the study of Buchheit, Solano, Millet[31], it was found a strong relation between AT determined by HRDP, by HR variability, and by the ventilatory method in young boys and the authors attributed the occurrence of the HRDP to mechanically induced changes in myocardial function. In this perspective, it seems that an augmented myocardial function, represented by LVEF slightly increased, is a potential mechanism for regular HRDP[30]. The fact that HRDP is derived primarily from cardiac mechanical alterations and not from peripheral mechanisms, as the mitochondrial function or metabolic events, may explain the normal occurrence of HRDP in all participants of the present study. Possibly, the HRDP occurrence in more severe dyslipidemic patients, who already present cardiac complications, may be different. Therefore, the HRDP method during an incremental treadmill test can precisely and individually determines the intensity corresponding to the AT without expensive equipment, such as a gas analyser. This test is easy to perform, it is time-efficient and it only requires an HR monitor, a treadmill and a well-structured protocol with progressive increases in load. Experienced observers in visual analysis can determine the HRDP from the HR-by-intensity dispersion graph obtained from the incremental test. From this graph, it is possible to calculate the percentage of the HR corresponding to the AT in order to prescribe the desired training zone.

Some limitations could be highlighted, such as the analysis was not stratified by statins users or non-users, as it was also not stratified by the participants' level of physical activity; and the absence of a sample size calculation. On the other hand, the present study has some strength, such as: the determination of a simple and affordable method in a population of high prevalence, providing multiple information about a very important parameter (anaerobic threshold) in the physical training scenario.

Conclusions

It is possible to conclude that there is an agreement between the HRPD and VT methods in the determination of the AT in dyslipidaemic patients performing an incremental treadmill test. The findings demonstrated that both methods could be used in this population for the prescription of exercise training. These results have relevant clinical implications in demonstrating the possible use of a low cost easily applicable method for determination and control of the AT, which is a very responsive parameter of endurance training (aerobic/anaerobic). The knowledge on this parameter is important for safety and efficacy of exercise prescription and progression, especially in patients such as dyslipidaemic individuals.

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Corresponding author

Rochelle Rocha Costa
Universidade Federal do Rio Grande do Sul, 750 Felizardo Street, Porto Alegre (City), Rio Grande do Sul (State), Brazil. Postal Code 90690-200 - Telephone 55 51 33085820
Email: rochelle.costa@ufrgs.br

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